

Computer Graphics

Principles and Practice in C

Second Edition

James D. Foley • Andries van Dam
Steven K. Feiner • F. Hughes John

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Magic for the use of their laser scanner to create Plates II.24–37, and to Norman Chin for computing vertex normals for Color Plates II.30–32. L. Lu and Carles Castellsagué wrote programs to make figures.

Jeff Vogel implemented the algorithms of Chapter 3, and he and Atul Butte verified the code in Chapters 2 and 7. David Sklar wrote the Mac and X11 implementations of SRGP and SPHIGS with help from Ron Balsys, Scott Boyajian, Atul Butte, Alex Contovounesios, and Scott Draves. Randy Pausch and his students ported the packages to the PC environment.

We have installed an automated electronic mail server to allow our readers to obtain machine-readable copies of many of the algorithms, suggest exercises, report errors in the text and in SRGP/SPHIGS, and obtain errata lists for the text and software. Send email to “graphtext @ cs.brown.edu” with a Subject line of “Help” to receive the current list of available services. (See page 1175 for information on how to order SRGP and SPHIGS.)

Preface to the C Edition

This is the C-language version of a book originally written with examples in Pascal. It includes all changes through the ninth printing of the Pascal second edition, as well as minor modifications to several algorithms, and all its Pascal code has been rewritten in ANSI C. The interfaces to the SRGP and SPHIGS graphics packages are now defined in C, rather than Pascal, and correspond to the new C implementations of these packages. (See page 1175 for information on obtaining the software.)

We wish to thank Norman Chin for converting the Pascal code of the second edition to C, proofreading it, and formatting it using the typographic conventions of the original. Thanks to Matt Ayers for careful proofing of Chapters 2, 3, and 7, and for useful suggestions about conversion problems.

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equal to zero, defining a closed polygon in the plane (the polygon's edges are $v_1v_2, v_2v_3, \dots, v_{n-1}v_n, v_nv_1$). You wish to define a polyhedron that consists of this object, extruded along the z axis from $z = 0$ to $z = 1$. Assume a right-hand coordinate system.

- How would you check that the polygon $v[1], \dots, v[n]$ is counterclockwise (i.e., as you traverse the edges of the polygon, its interior is to your left)?
- Describe an algorithm for generating the polygons of the extruded object. For the "sides," you can either use rectangular faces or divide them into triangles. The descriptions of these polygons should be indices into a list of vertices.
- Each of the faces given in part (b) consists of a list of vertices. Suppose that you walk around the boundary of a polygon, and the polygon interior is to your right. Did you choose your order for the vertices so that the exterior of the extruded polyhedron is always overhead? If not, modify your answer to part (b).
- Each edge of the extruded polyhedron is part of two faces, so during the traversals in part (c), each edge is traversed twice. Are the two traversals always in the same direction? Always in opposite directions? Or is there no particular pattern?

A.4 Given that $P = (x_0, y_0)$ and $Q = (x_1, y_1)$ are points in the plane, show that the equation of the line between them is $(y_1 - y_0)x - (x_1 - x_0)y = y_1x_0 - x_1y_0$. This formulation is especially nice, because it provides a general form for lines in any direction, including vertical lines.

A.5 Given that $\mathbf{v} = \begin{bmatrix} x \\ y \end{bmatrix}$ is a vector in the plane, show that $\mathbf{w} = \begin{bmatrix} -y \\ x \end{bmatrix}$ is orthogonal to it. This is sometimes called (in analogy with the corresponding case in 3D) the cross-product of a single vector in the plane. The cross-product of $n - 1$ vectors in $\mathbf{R}^n$ can also be defined.

A.6 If P, Q , and R are three points in the standard affine 3-space, then

$$\frac{1}{2} \| (Q - P) \times (R - P) \|$$

is the area of the triangle ΔPQR . If P, Q , and R all lie in the xy plane in the standard affine 3-space, then

$$\frac{1}{2} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \cdot ((Q - P) \times (R - P))$$

gives the *signed area* of the triangle—it is positive if ΔPQR is a counterclockwise loop in the plane and negative otherwise. (Counterclockwise here means "counterclockwise as viewed from a point on the positive z axis, in a right-handed coordinate system.")

- Find the signed area of the triangle with vertices $P = (0, 0)$, $Q = (x_i, y_i)$, and $R = (x_{i+1}, y_{i+1})$.

Answer: $\frac{1}{2} (x_i y_{i+1} - x_{i+1} y_i)$

- Suppose we have a polygon in the plane with vertices $v_1, \dots, v_n$ ($v_n = v_1$), and $v_i = (x_i, y_i)$ for each i . Explain why the signed area of the polygon is exactly

$$\frac{1}{2} \sum_{i=1}^{n-1} x_i y_{i+1} - x_{i+1} y_i$$

Compare this with Eq. 11.2.

A.7 The Gram-Schmidt process described in Section A.3.6 for three vectors can be slightly simplified. After computing $\mathbf{w}_1$ and $\mathbf{w}_2$, we seek a third unit vector, $\mathbf{w}_3$ which is perpendicular to the first two. There are only two choices possible: $\mathbf{w}_3 = \pm \mathbf{w}_1 \times \mathbf{w}_2$. Show that the Gram-Schmidt process chooses the sign in this formula to be the same as the sign of $\mathbf{v}_3 \cdot (\mathbf{w}_1 \times \mathbf{w}_2)$. This implies that if you know that $\mathbf{v}_1, \mathbf{v}_2, \mathbf{v}_3$ is positively oriented, then you need not even check the sign: $\mathbf{w}_3 = \mathbf{w}_1 \times \mathbf{w}_2$.

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